Adjusting for New Normals: Adapting Buildings to Extreme Heat and Power Outages

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'Unprecedented' **early heat wave** sets new records. **Fire danger** is high. [July 6, 2018.]

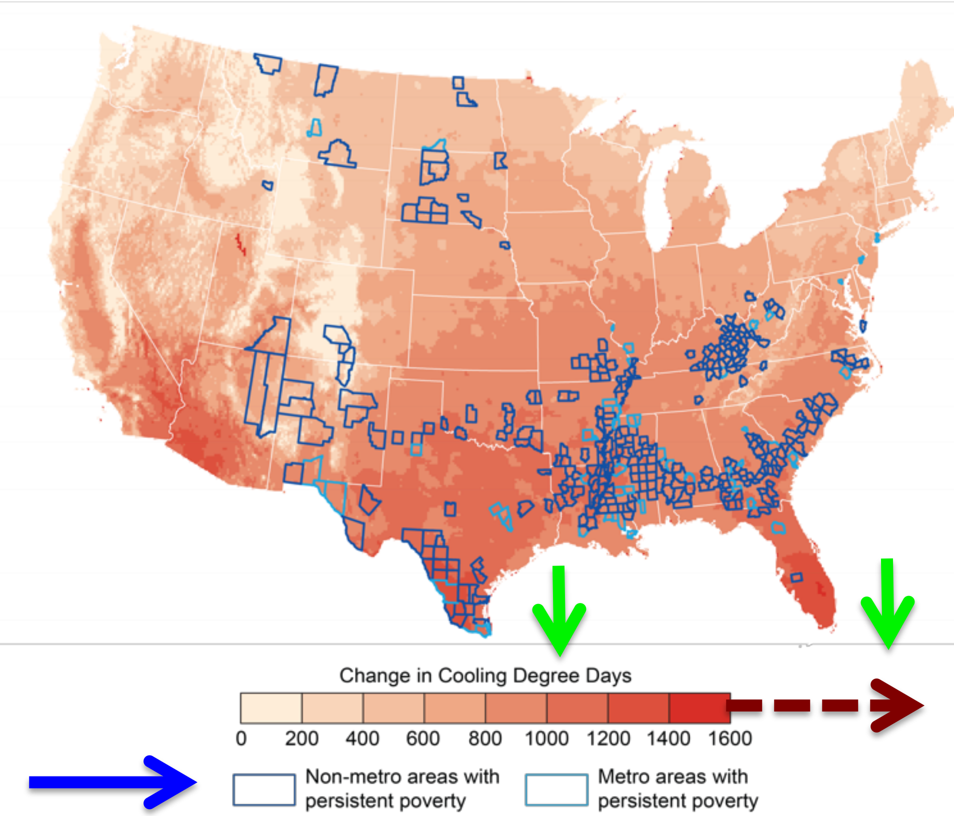
Over **12,000 still without power** in L.A. after **3 days** of record heat and **record power demand.** [July 9, 2018].

Image: adapted from Mike Luckovich, 2012. http://www.gocomics.com/mikeluckovich/2012/07/06/.

Climate Change Impacts: Cooling Demand

- Increased cooling demand (Cooling Degree Days/year) [1]
  - Mid-century: + > 1,000 CDD in many regions
  - Late century: + > 2,000 CDD in many areas [2]
  - Energy poverty and/or AC lacking in many areas (blue boxes)
- Major impacts on energy costs, grid demand, grid outages, and health

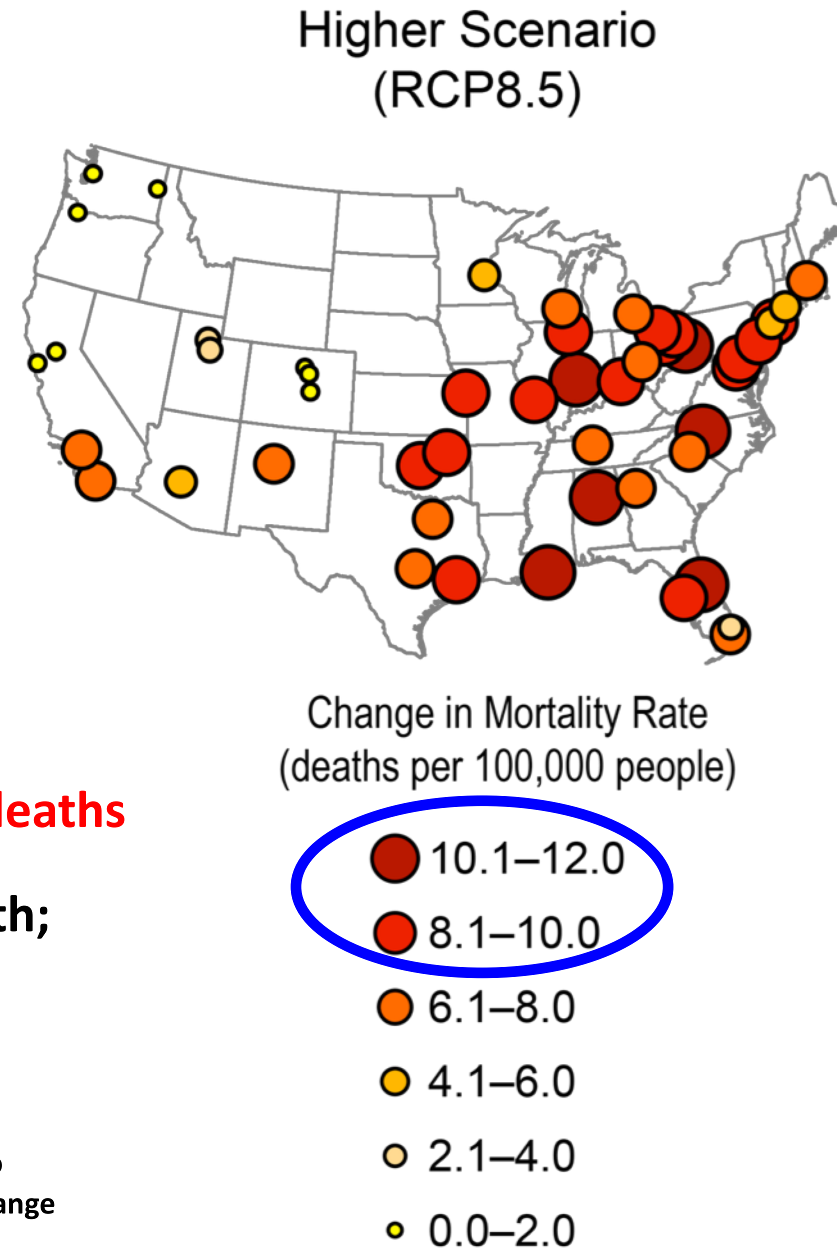
CDD Increase by Mid-Century, RCP 8.5 [1]



1. USGCRP, 2018. Fourth National Climate Assessment, Vol. 2. Fig. 14 and 19. https://nca2018.globalchange.gov/chapter/front-matter-about/.
2. Petri & Caldeira, 2015. https://www.nature.com/articles/srep12427.

Climate Change Impacts: Mortality

- **Increased U.S. mortality from extreme heat & cold** [1]
  - Late century: up to 9,300 deaths/year across 49 cities (1/3 of US population)
  - Very high risk in many cities: ≥ 10 per 100,000 risk (10^{-4} risk)
  - $140 billion/year (in 2015 dollars)
  - RCP 8.5, no adaptation



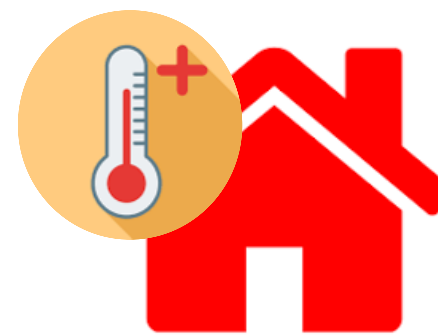
- **California heat-related mortality** [2]
  - 650 deaths in 2006 heat wave
  - Late century, seniors: 4,700 – 8,800 deaths per year
    (9 urban metro areas; medium growth; 5 models; no adaptation)

1. USGCRP, Nov. 2018. Fourth National Climate Assessment, Vol. 2. Figs. 14.4 and 19.22 . https://nca2018.globalchange.gov/chapter/front-matter-about/.
2. Sheridan et al., 2011. A spatial synoptic classification approach to projected heat vulnerability in California under future climate change scenarios. CARB Seminar, Final Report, and journal articles.

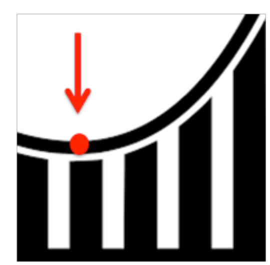
Study Objectives

- Design new single family ZNE home in **Bakersfield, CA**
  - Healthy, resilient, and affordable
  - 2019 CA building energy standards: Title 24

- Examine impacts of 2006 Heat Wave, Climate Change, and Power Outages on:
  - Overheating of home
  - Time Dependent Value (TDV) Energy

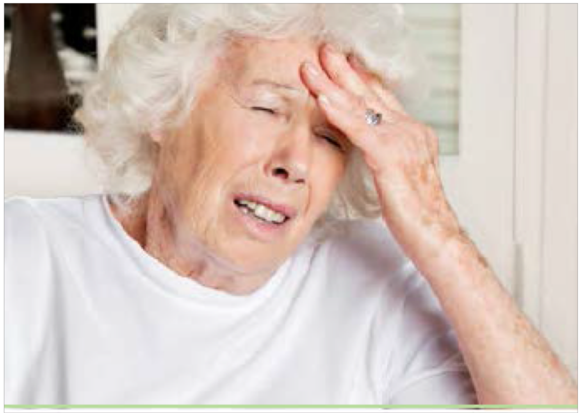


- Optimize home performance for energy cost (TDV), and ultimately Carbon emissions, in Bakersfield
  and then in future climate.

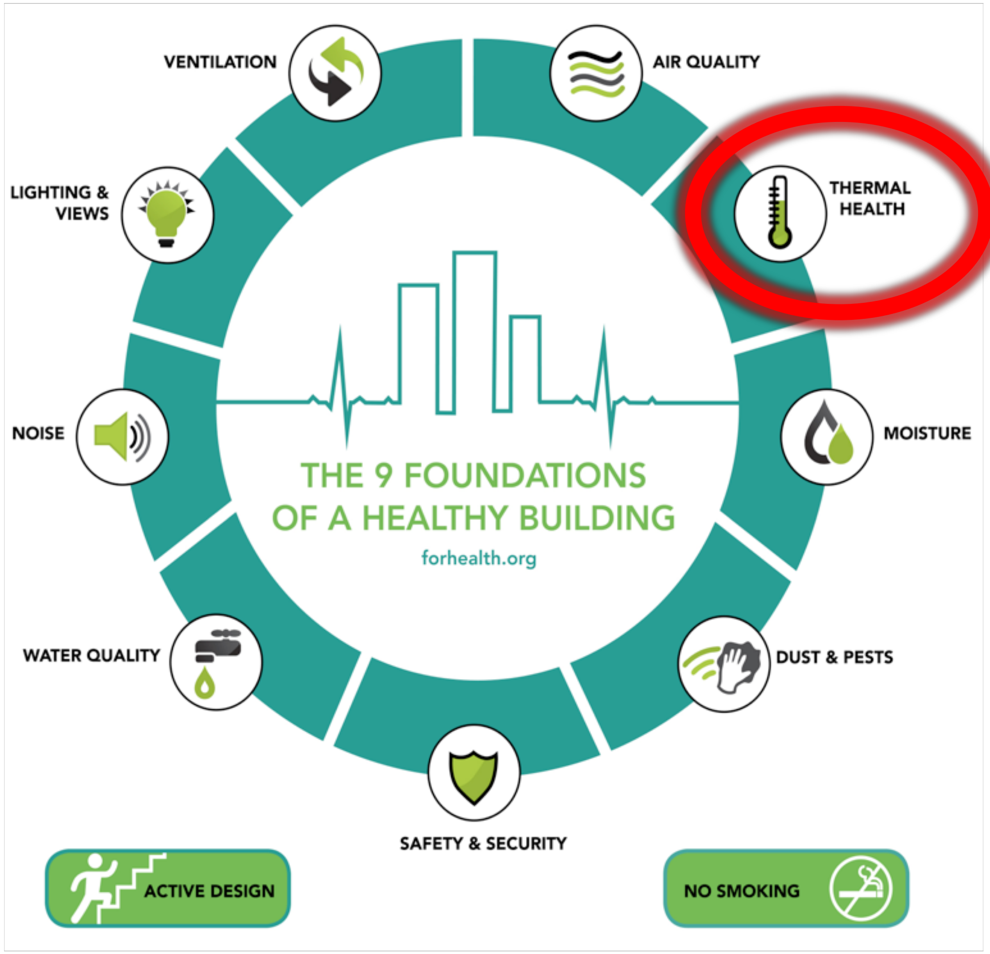


Methods

- **Overheating Metrics**
  - **Discomfort Index (DI)**
  - **Wet Bulb Global Temperature (WBGT)**

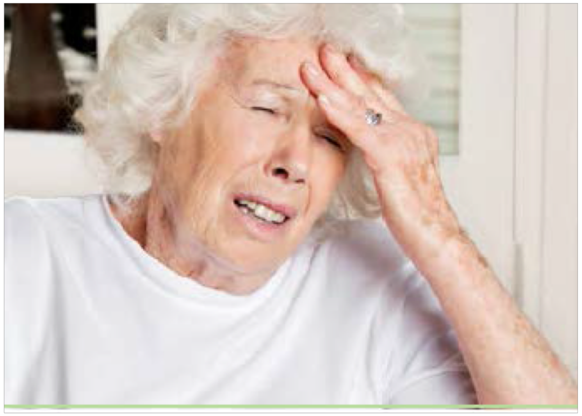


[Zero Carbon Hub, 2013. Overheating in Homes: Where to Start.]

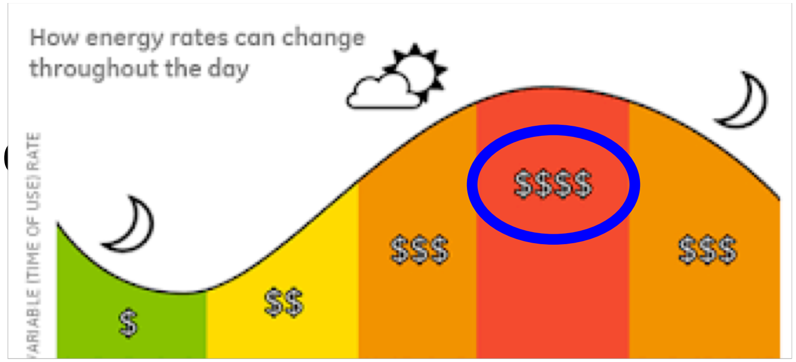


9 Foundations For Health.

Methods (2)



- **Overheating Metrics**
  - Discomfort Index (DI)
  - Wet Bulb Global Temperature (WBGT)
- **Time Dependent Value Energy (TDV) and Total Energy Use**
  - TDV driven by peak cooling demand
  - Site Energy per year
  - CBECC-Residential software for CA building standards



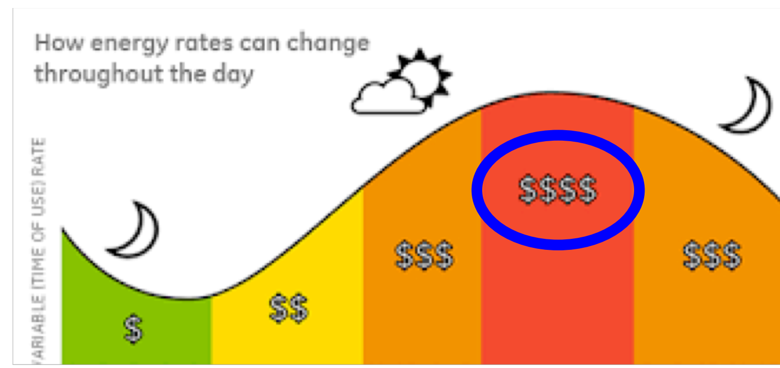
Time of Use Rates

Heat health image: Zero Carbon Hub, 2013. Overheating in Homes: Where to Start. http://www.zerocarbonhub.org/current-projects/tackling-overheating-buildings
TDV image: Time of Use utility rates. GE, in CPUC, Residential Rate Reform Through 2019.

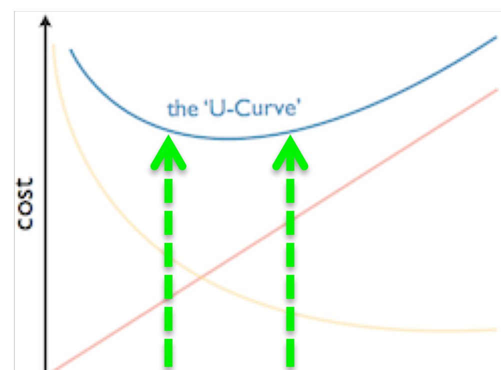
Methods (3)

- **Overheating Metrics**
  - **Discomfort Index (DI)**
  - **Wet Bulb Global Temperature (WBGT)**

- **Time Dependent Value Energy (TDV) and Total Energy Use**
  - **CBECC-Residential model for CA building standards**



- **Building Optimization**
  - **Optimize for TDV, cooling energy, and carbon emissions**
  - **BeOpt model (NREL, free tool)**



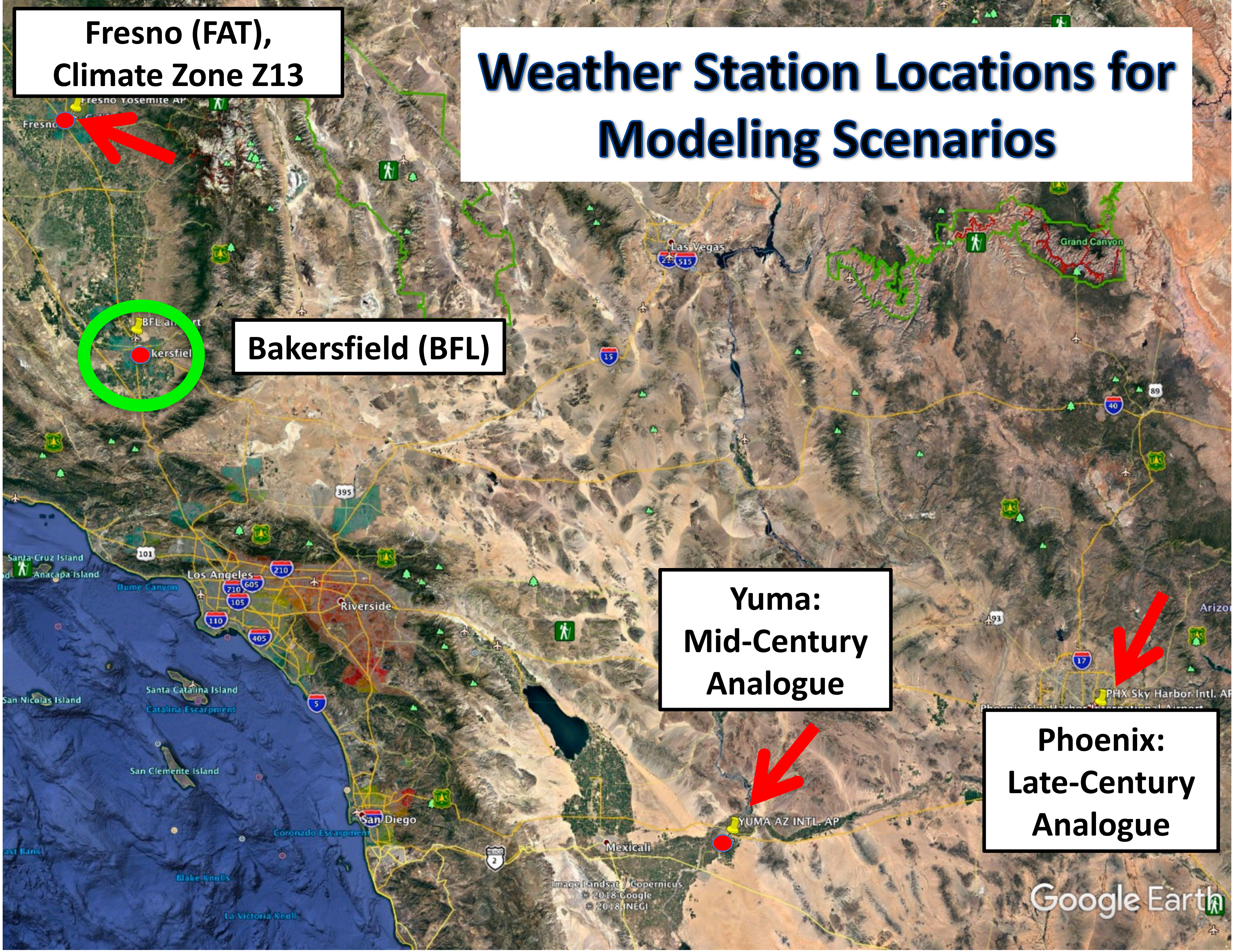
TDV image: Time of Use utility rates. GE, in CPUC, Residential Rate Reform Through 2019.
U Curve image: Donald Peterson at Fabok, 2013. https://zsoltfabok.com/blog/2013/03/the-optimal-batch-size/.

Methods: Modeled Scenarios

- CA Climate Zone 13, Fresno (CZ13)
  - *Typical historical weather, used in building standards*
- Bakersfield 2006 Heat Wave (BFL)
  - *Extreme historical case*

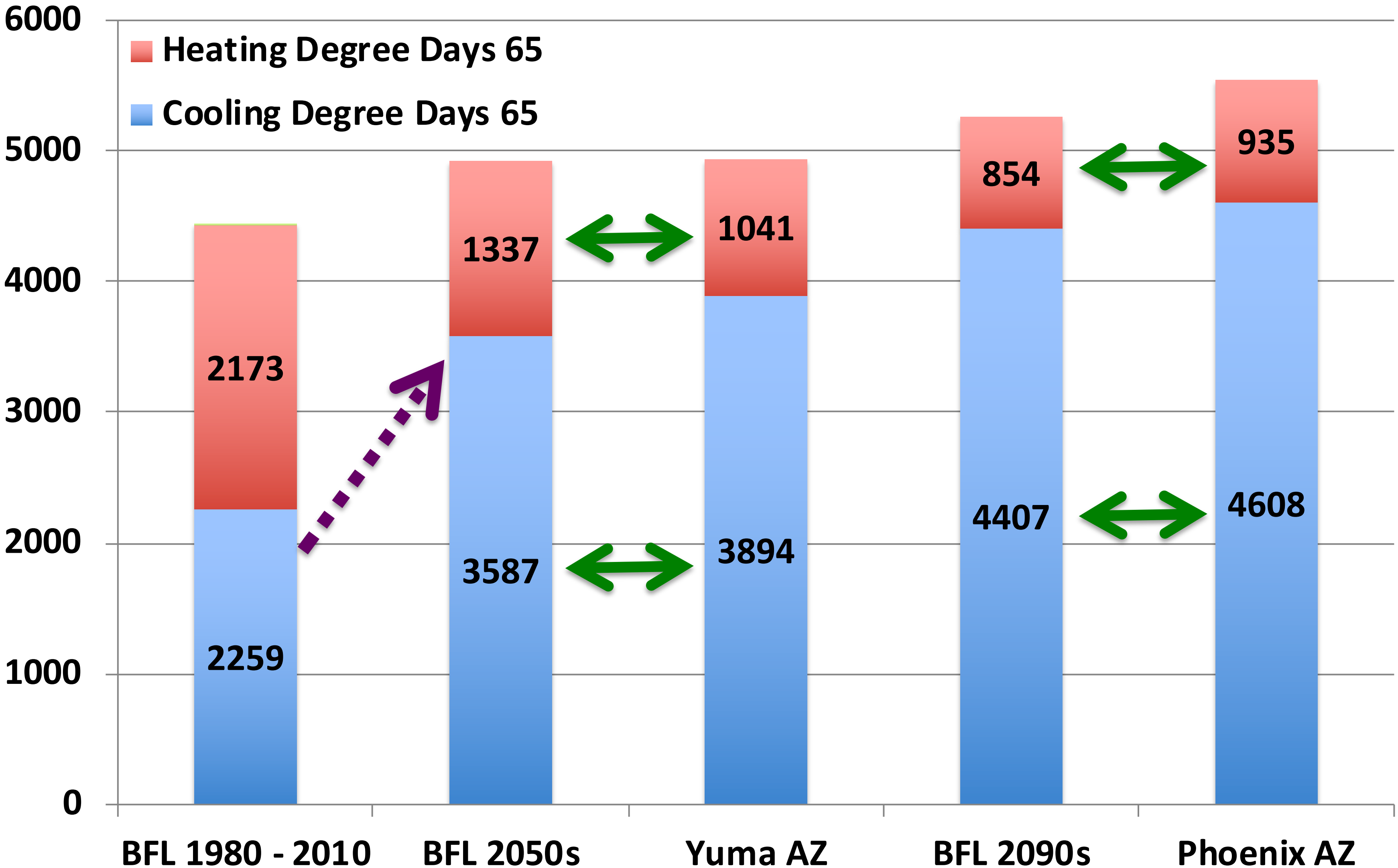
- Future Climate: Analogue cities *(Yuma and Phoenix)*
  - ***Reasonable worst case***
- Power Outages for current and future climates
  - ***Near-Worst cases***
    (no heat wave)

Heatwave Warning image: L. Young, Using Climate Data to Make Buildings Climate Proof. CIBSE Journal, March 2016.



Weather Station Locations for Modeling Scenarios
Fresno (FAT), Climate Zone Z13
Bakersfield (BFL)
Yuma: Mid-Century Analogue
Phoenix: Late-Century Analogue
Fresno Yosemite AP
BFL airport
Las Vegas
Grand Canyon
Los Angeles
Riverside
San Diego
Mexicali
YUMA AZ INTL. AP
PHX Sky Harbor Intl. AP
Santa Cruz Island
Anacapa Island
Santa Catalina Island
San Nicolas Island
San Clemente Island
Image Landsat / Copernicus
© 2018 Google
© 2018 INEGI
Google Earth

CDD and HDD: BFL Historical and Cal Adapt vs. Climate Analogue Cities

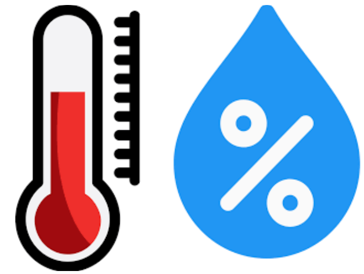


1. Cal-Adapt, 2018. Tools. Cooling and Heating Degree Days. East Bakersfield, RCP 8.5, 10 year average. https://cal-adapt.org/tools/.
2. NCDC, 1981-2010 Climate Normals. https://www.ncdc.noaa.gov/cdo-web/datatools/normals.

Overheating: Metrics for Public Health

- **Discomfort Index (DI)**

  DI = (0.5 * T dry bulb) + (0.5 * T wet bulb) [1]



- **Targets:**

  ≥ 22 °C (71.6 °F) Mild: under 50% feel discomfort [2]

  ≥ 24 °C (75.2 °F) Moderate: 50% or more feel discomfort [2]

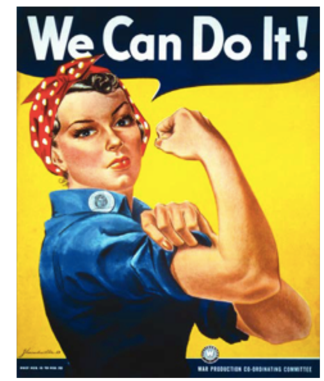
  ≥ 28 °C (82.4 °F) Severe: Most suffer discomfort [2]

1. Baniassadi and Sailor (2018).
2. Epstein and Moran (2006).

Overheating Standards and Guidelines: *International*

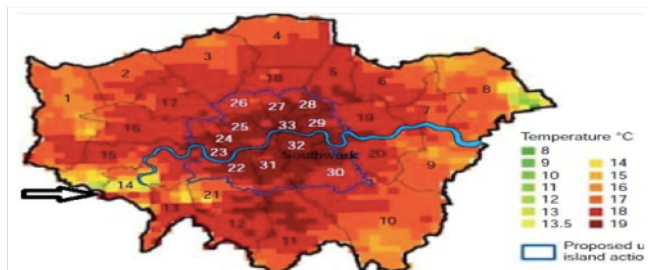
e: Albert, Righter and Tittmann Architects

- **Passive House Program:**
  ≤ 10% (h/y) > 25 C, and moisture limit [1]



- **CIBSE TM 59 Overheating Design Guide (UK):**
  1-3 % (h/y) overheating limits by room type;
  future climate scenarios recommended. [2,3]

- **CIBSE TM 49 Urban Heat Island Design Guide**
  (UK and London Plan):
  Overheating risk assessment for
  urban heat zones. [4]

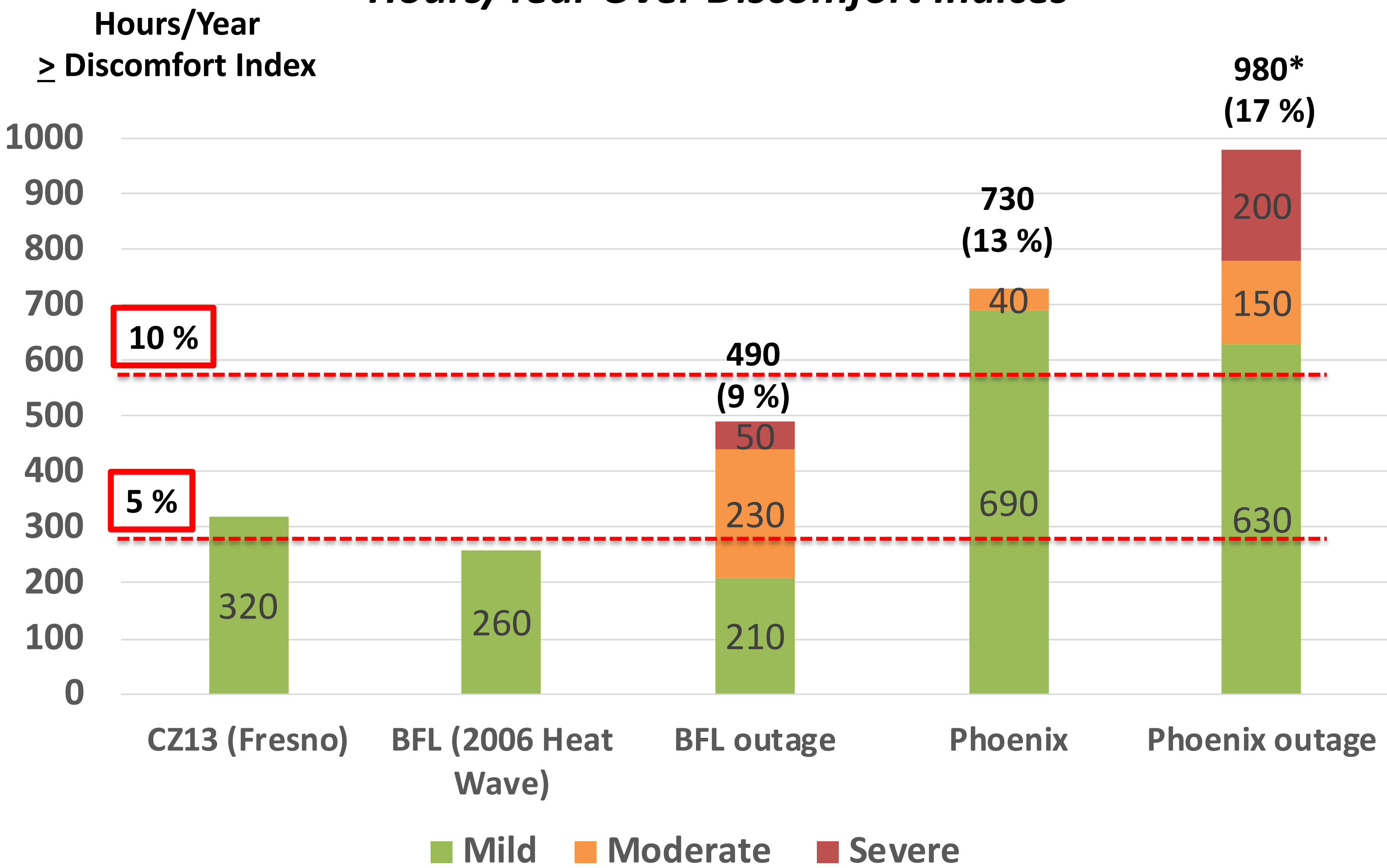


Average outdoor air temperature in London during August 2013

1. Passive House Institute, 2016. Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard.
2. CIBSE, 2017: TM 59, Design methodology for the assessment of overheating in homes.
3. Diamond, S., May 22, 2017. TM 59 webinar. Inking Associates.
4. CIBSE, 2014. TM49 Design Summer Years for London. See also: ARCC Network, 2017. Designing for Future Climate.

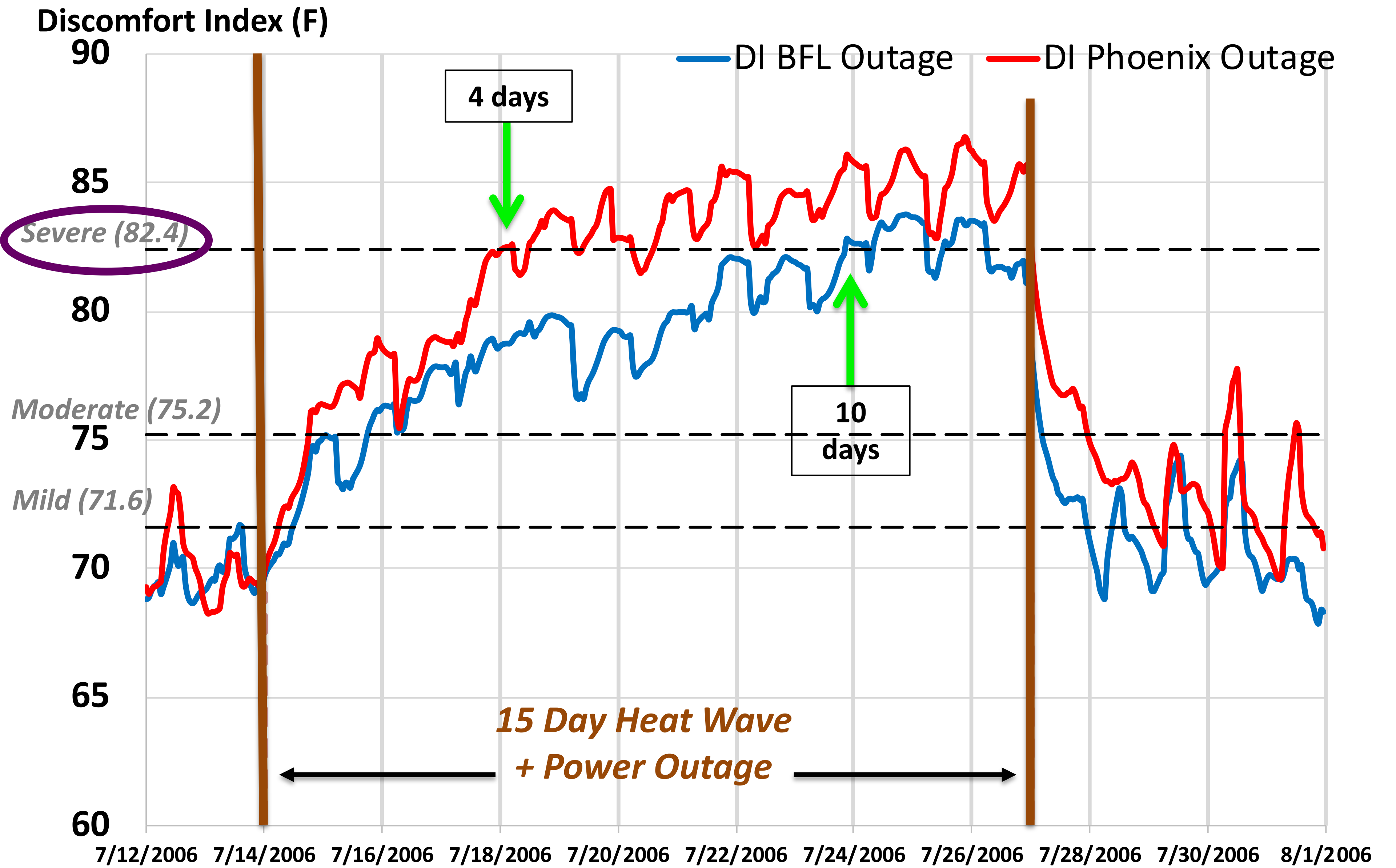
Preliminary Results: Overheating

Hours/Year Over Discomfort Indices

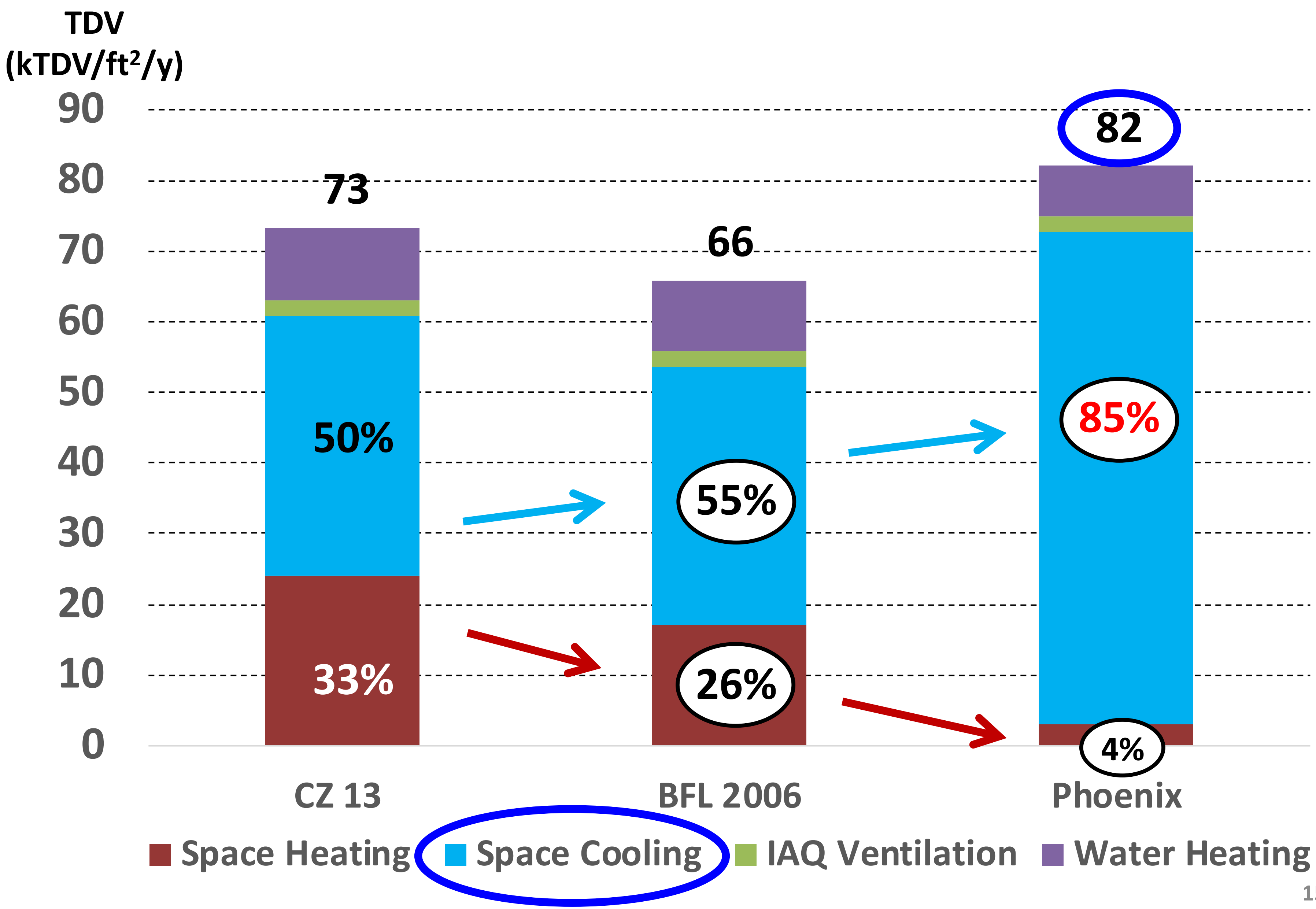


* Outage period is simulated only for 15 days (July 14 – July 28), as occurred in BFL 2006.

BFL and Phoenix DI: Heat Wave + Outage



Preliminary Results: TDV and % of Total TDV



BeOpt Model: Optimizing Multiple Measures

SCREEN related categories, stepwise: Each with several options

↓

OPTIMIZE all categories: Use top 2-3 options for TDV and Cooling Energy

↓

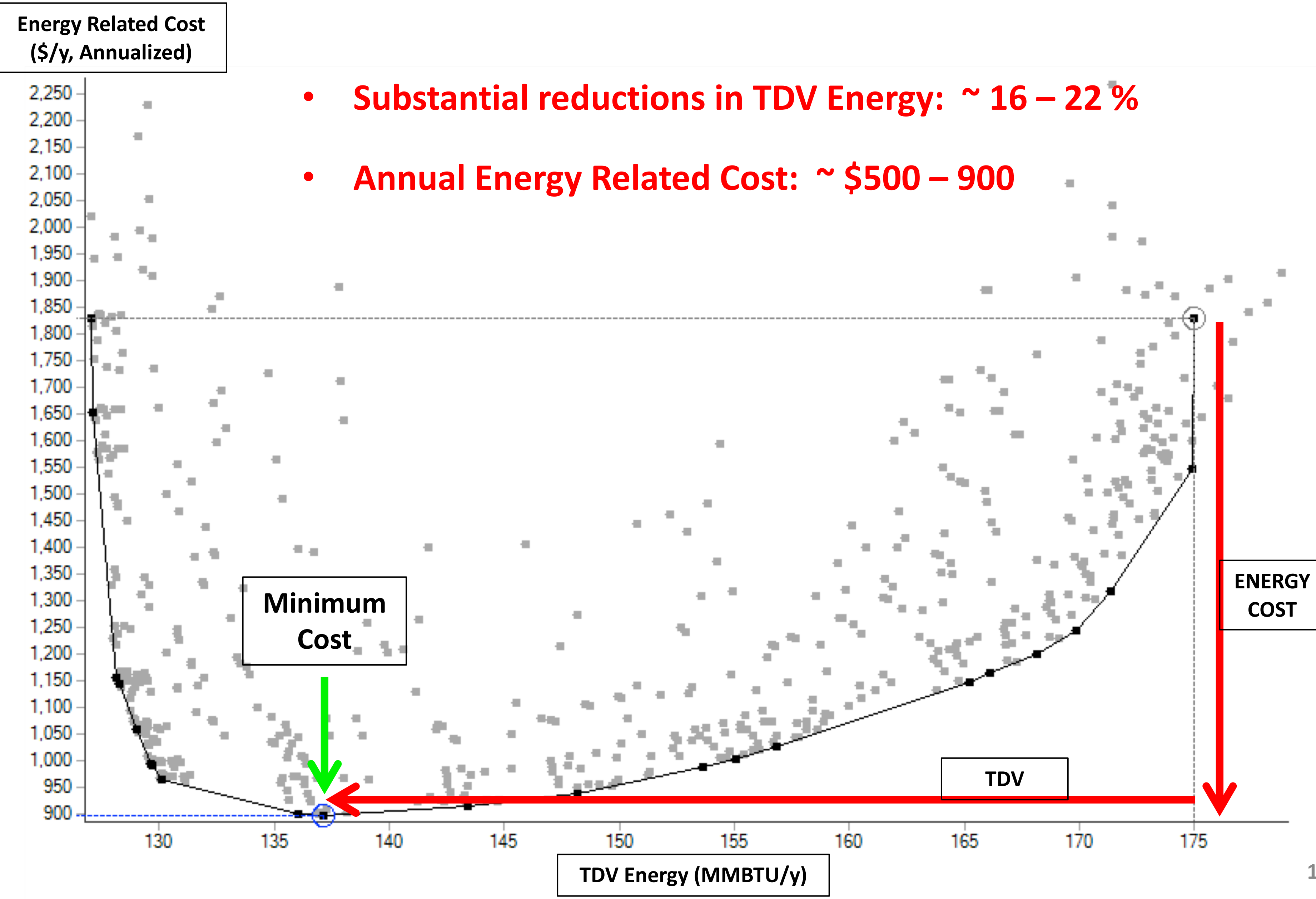
Add PV to meet Site Energy need: Test a range of sizes

Optimization Categories	
1.	Building Site
2.	Walls
3.	Ceilings/Roofs
4.	Foundation/Floor
5.	Thermal Mass
6.	Windows/Doors/Shading
7.	Air Flow
8.	Space Conditioning
9.	Water Heating
10.	Lighting
11.	Appliances & Fixtures & Schedules
12.	MISC: plug loads & other appliances
13.	PV

BeOpt Results (Preliminary): Energy Costs vs. TDV

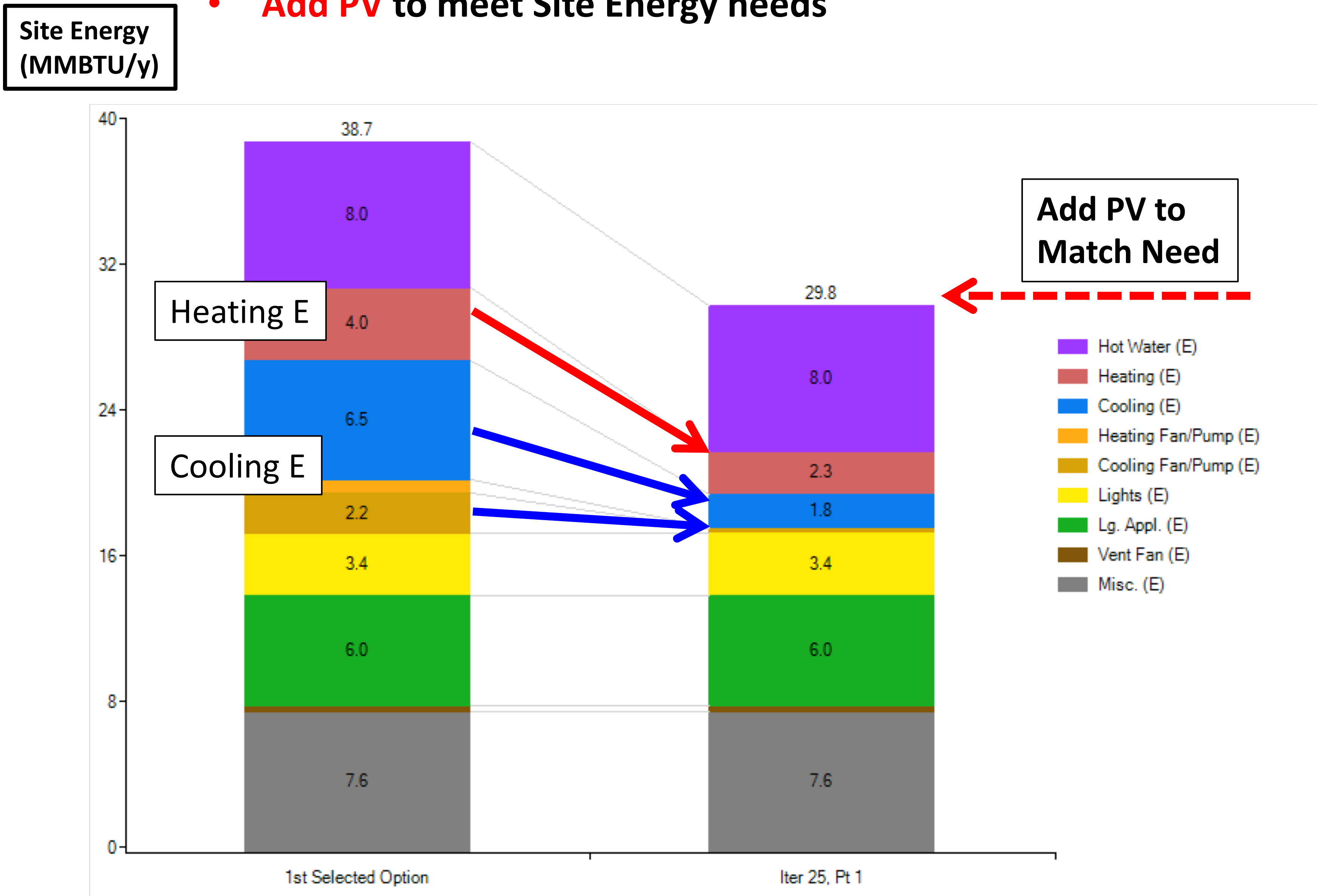
Title 24 Single Family box prototype, 2100 ft², 3 BR, no PV

- **Substantial reductions in TDV Energy: ~ 16 – 22 %**
- **Annual Energy Related Cost: ~ $500 – 900**

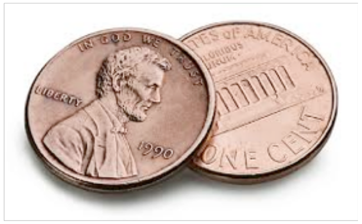


BeOpt Full Optimization: Site Energy Example

- Total Site E Reduction: ~ 9 MMBTU/y (23%)
- Add PV to meet Site Energy needs



Overheating Standards and Guidelines:
*North America: Input Needed **



- ✓ **Build It Green (2016): GreenPoint Rated 7.0 (CA Homes)** [1]
- ✓ **LEED/RELi (2018 update) Pilot Credit: Resilient Design 2.0** [2]
- ✸ **Collaborative for High Performance Schools Criteria (U.S.)** [3]

2018 Update: Dec. 6 webinar; Dec. 10 Comments !

- ✸ **California Title 24 Building Energy Efficiency Standards, and BC climate adaptation plan** [5]

2019: Weather files update & future weather files !!

- ✸ **Cal-Adapt climate tools update (CA)** [6]

Dec. 5 webinar; User input sought !

- ✸ **California PUC to address strategies and guidance for climate adaptation for electric and natural gas utilities.** [4]

Schedule TBD !

⌘ **Big Boom in research papers on overheating.**

1. Build It Green, 2017. Version 7.0 Update, Executive Summary.
2. Wilson, A., 2018. The LEED credits are back up.
3. CHPS 2018 draft update and webinar.
4. J. Huang, White Box Technologies. Personal communication, Nov. 21 ,2018.
5. Cal-Adapt. https://cal-adapt.org/blog/2018/webinar-december/.
6. Filings at the CPUC, May 2018. www.cpuc.ca.gov/.../CPUC_Website/.../Filings%20newsletter%202018-05.pdf

CONCLUSIONS

- **Modeling and measurement tools are available** to assess and mitigate overheating and energy use impacts of climate change, and to keep buildings healthy and resilient (survivable).
- There are **some signs of progress** in addressing this problem in N. America – perhaps even an inflection point.
- But we **must integrate climate adaptation to extreme heat** into all programs & policies -- **NOW**.

ARCC, 2017. Bicester NW EcoDevelopment. Fact sheet and Masterplan Final Report (2013).

Thank you for your attention!!

Thought For the Day:

BE PREPARED for Extreme Conditions

Song for the Day:

Shapes of Things, Yardbirds

http://www.songfacts.com/detail.php?lyrics=11391

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Grand Canyon National Park

BONUS SLIDES

PHILLIPS & HIGBEE: RECOMMENDATION

Provide and promote future proof, healthy, and resilient buildings that adapt to and mitigate climate change, especially for extreme heat.

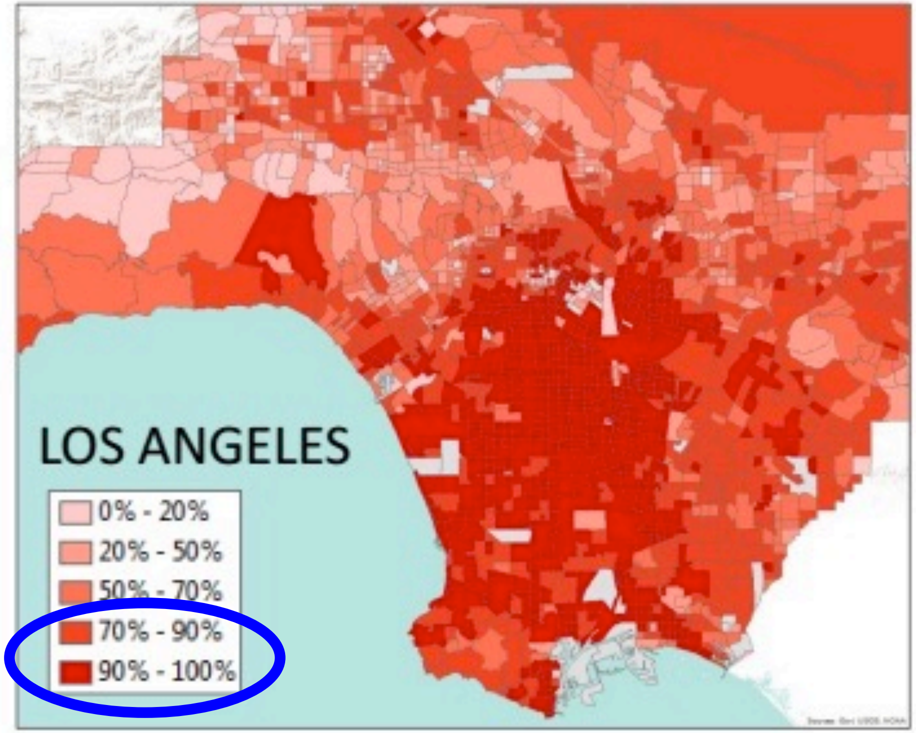
- ✓ **Assess climate vulnerability to extreme heat using future weather files, and design for full life cycle optimization.**
- ✓ **Include passive cooling measures in retrofit programs, targeting heat vulnerable buildings and populations.**
- ✓ **Update building standards and design guidelines now.**
- ✓ **Educate and train building, planning, & health professionals.**
- ✓ **Accelerate market demand through improved financing, incentives, demonstrations, and marketing for future proof buildings.**

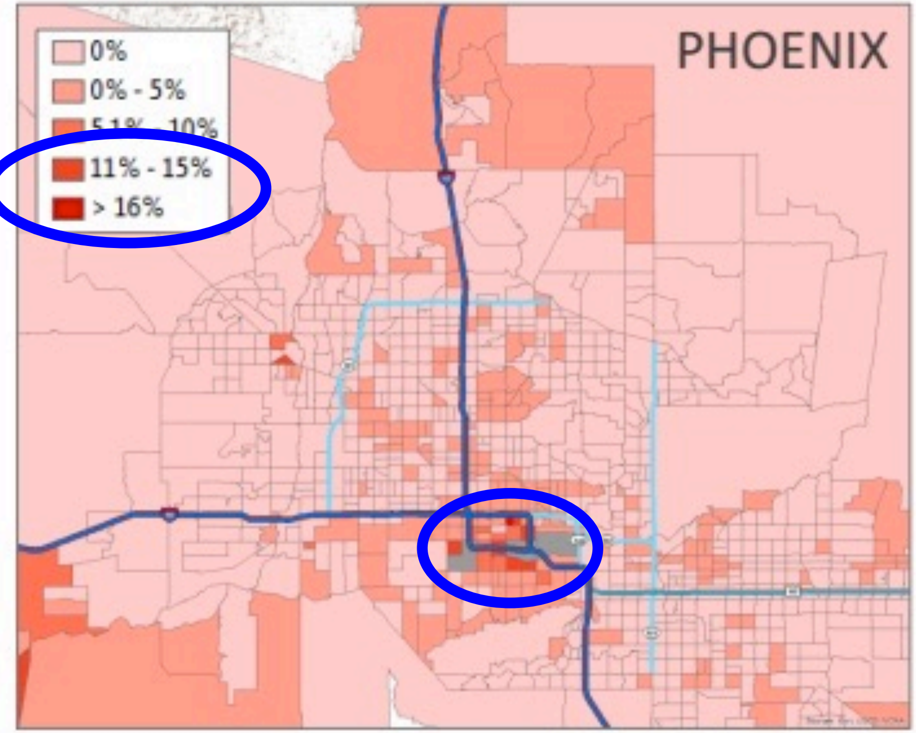
Why is Indoor Heat Exposure So Important?

- Mortality & Morbidity
  - Europe 2003 Heat Wave
  - California 2006 Heat Wave
  - Even moderate heat increases health risks
  - Many deaths occur indoors
  - Most long term exposure is indoors, especially for vulnerable persons
  - New CA homes were often too hot

- Climate Change is increasing:
  - Extreme heat (frequency, intensity, duration)
  - Especially nighttime heat (sleep deprivation)
  - Increasing humidity in CA and NE
  - Wildfires, pollen, air pollution
  - Mold from flooding
  - Urban Heat Island, land development
  - Power outages

Homes *Without* Central AC: L.A. vs. Phoenix *





- **LA homes:** **very high percentage lack Central AC**, **especially near the coast, in the LA Basin, and in low income areas**
- **Phoenix homes: very low percentage lack Central AC, but** **high in low income and older neighborhoods**

* Chester et al., Sept. 9, 2015 presentation. [Pioritizing Cooling Infrastructure Investments for Vulnerable Southwest Populations](). ASU/UCLA study. AC status based on property tax records regarding central air systems, etc.
See also: Reyna & Chester, 2017 re: projected electricity demand in L.A. County. https://www.nature.com/articles/ncomms14916.

Preliminary Results: Summary

- **Overheating in a new Bakersfield ZNE home:**
  - Historical and heat wave conditions: mild DI at a modest level (~5 % of hours/y).
  - Future climate and power outage conditions: more extensive and intense DI (9 – 17 % hours/y), especially in the late century climate (Phoenix).
  - Future climate conditions: large increase in total TDV, and cooling TDV accounts for 82% of that.
  - Outage + Heat Wave conditions: severe DI occurred by 5th day in the current climate, and by the 1st day in the future climate.
- **Optimization modeling:**
  - Results suggested the energy efficiency measures can achieve major reductions in current and future TDV and carbon emissions.
  - Reductions in overheating frequency, duration, and intensity are expected also.

Indoor Overheating Standards and Guidelines: *International ADD IMAGES*

- **Passive House Program: Overheating specifications.** [1]
  - **≤ 10% of hours > 25 C (≤ 5 % used by some); static model**
  - **Absolute humidity criteria of <12 g/kg**

- **CIBSE TM 59 Overheating design guide (UK).** [2]
  - **25 – 28 C Operative Temperature (T & RH)**
  - **Time and temperature limits for different occupancies and rooms**
  - **Recommended: assess for 2050s and 2080s climates under high & medium emissions scenarios**
- **CIBSE TM 49 Urban Heat Island design guide.** [4]
  - **Overheating assessed using Design Summer Year weather data**
  - **Urban heat zones are mapped for London and other cities**

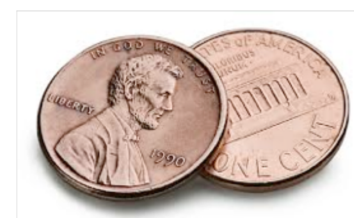
1. Passive House Institute, 2016. Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard.
2. CIBSE, 2017: TM 59, Design methodology for the assessment of overheating in homes.
3. Diamond, S., May 22, 2017. TM 59 webinar. Inking Associates.
4. CIBSE, 2014. TM49 Design Summer Years for London. See also: ARCC Network, 2017. Designing for Future Climate.

Indoor Overheating Standards and Guidelines: *North America: Input Needed **

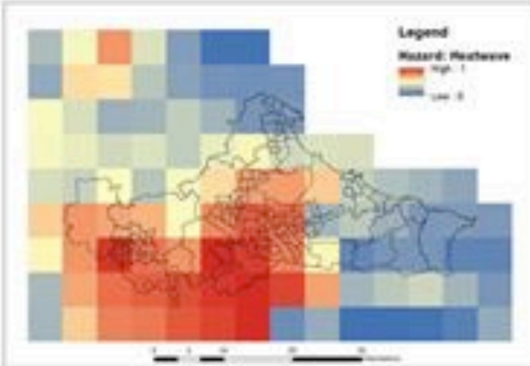
- **Build It Green (2016): GreenPoint Rated 7.0 (CA Residential)** [1]
- *** Collaborative for High Performance Schools Criteria (U.S.)** [2]
  - **2018 Update: December 6 webinar**
  - **Public comments due Dec. 10**

- **LEED/RELi Pilot Credit 2018: Resilient Design 2.0 (N. America),** [3]
  - **Updated November 2018**

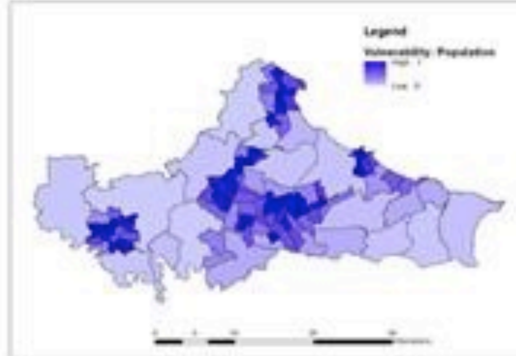
- *** California PUC begins to address strategies and guidance for climate adaptation for electric and natural gas utilities.** [4]
- *** California Title 24 Building Energy Efficiency Standards** [5]
  - **Weather file update to 2006 - 2017; due early 2019 !**
  - **Future weather files: considered for next Title 24 update !!**
  - **Cal-Adapt climate tools update:**
    December 5 webinar, Practitioner Input [6]



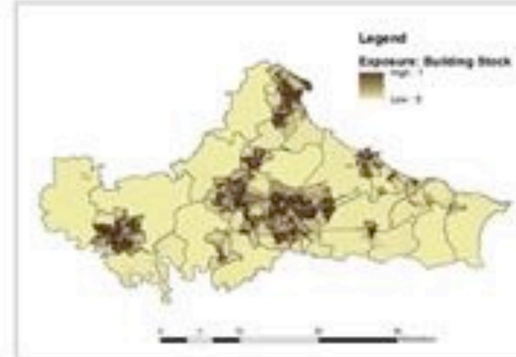
1. Build It Green, 2017. Executive Summary: Updates to GreenPoint Rated Version 7.0, New Single Family and Multifamily Programs.
2. Wilson, A., 2018. https://www.resilientdesign.org/the-leed-pilot-credits-on-resilient-design-are-back-up/.
3. CHPS draft criteria and webinaer: https://chps.net/news-announcements, https://chps.net/event/chps-national-core-criteria-%E2%80%93-introduction-2018-update.
4. Filings at the CPUC, May 2018. www.cpuc.ca.gov/.../CPUC_Website/.../Filings%20newsletter%202018-05.pdf
5. J. Huang, White Box Technologies. Personal communication, Nov.21 , 2018.
6. Cal-Adapt. https://cal-adapt.org/blog/2018/webinar-december/.



Hazard: UKCP09 climate projections of average summer Tmax and heatwave frequency

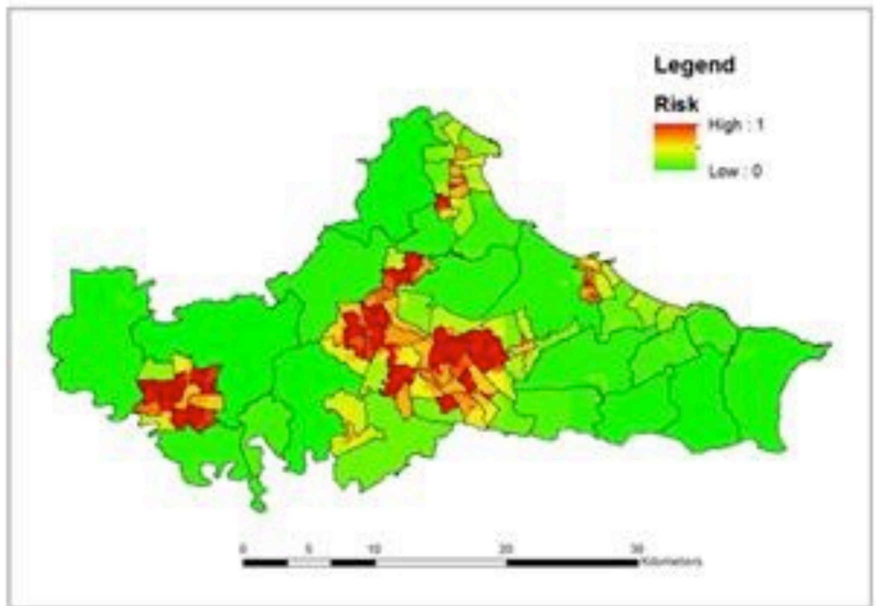


Vulnerability: Densities of young, old, long term illness and population requiring care



Exposure: Densities of low insulated buildings and high rise flats

Mapping Heat, Health, and Vulnerable Buildings

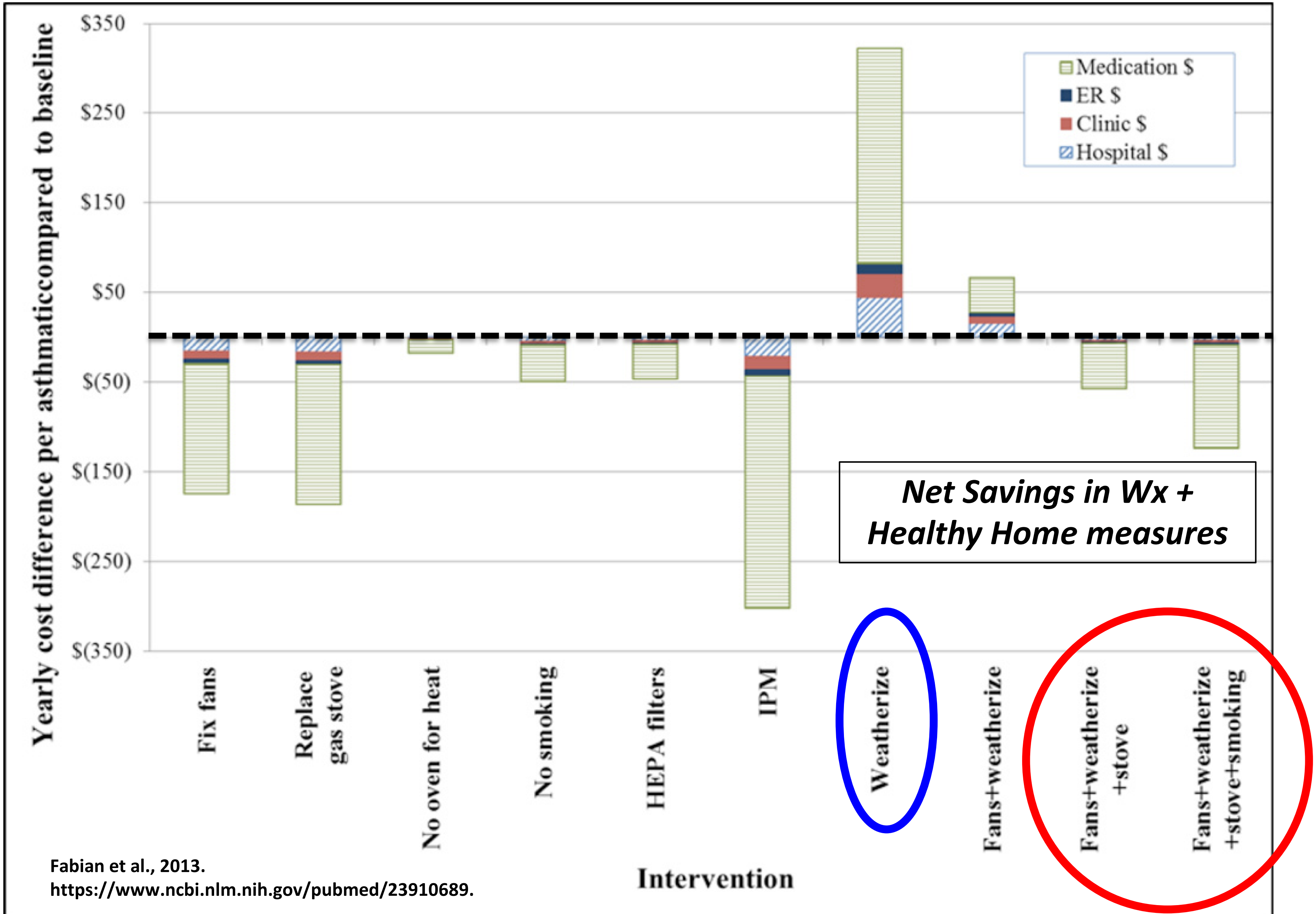


Risk: Relative risk based on three constituents, hazard, vulnerability and exposure

Newcastle University, 2013. Tees Valley Heat Risk Mapping. Centre for Earth Systems Engineering Research (CESER).
http://www.ncl.ac.uk/ceser/researchprogramme/impactengagement/teesvalleyheatriskmapping/.
SEE ALSO: Heat mortality risk and housing mapping of London, ARCC Network 2017.

Weatherization and Asthma Home Intervention Impacts:

Modeled Annual Cost Changes per Asthmatic in Low Income MFam Households



Fabian et al., 2013.
https://www.ncbi.nlm.nih.gov/pubmed/23910689.